

REVIEW AND DISCUSSION

1. Looking at the data in the text, we can see that the diameter of the Sun is about 100 times that of Earth, about 1,500,000 km for the Sun compared to about 12,000 km for Earth. A galaxy such as the Milky Way is about 100,000 light-years in diameter. Since a light-year is about 10^{13} km, this means the Galaxy has a diameter of approximately 10^{18} km, or about 10^{14} times (100 million million times) the radius of Earth. The most distant objects visible define the limits of the *visible* universe (which is likely only a small part of the entire universe). These objects are about 10 billion light-years away, or 10^{23} km. This is 10^{19} times (10 billion billion times) the radius of Earth.
2. The universe is defined as the sum total of all space, time, energy, and matter.
3. The scientific method is a process for discovering the best possible explanation as to why something occurs. The process begins when observations lead to the formulation of a hypothesis, a preliminary explanation that makes testable predictions. Investigators gather information – called data – to test the predictions through observation and experimentation. The information is analyzed to find patterns in the data. If the patterns agree with the predictions, the hypothesis is considered a viable theory. If they do not agree, the hypothesis must be discarded or modified. Science therefore relies on measurable quantities and testable predictions to search for answers. By contrast, religion relies on decree by authority or personal revelation through faith, neither of which are testable. If a claim is not testable, it cannot be considered scientific.
4. In the common usage of the term, a constellation is a pattern of stars in the sky. Officially, however, a constellation is a section of sky that contains stars, galaxies, nebulae, and many more celestial objects. Just as every section of Earth's land surface is considered part of a country, every part of the sky is within the borders of a constellation. Constellations are thus useful in naming and locating celestial objects.
5. The motion of the Sun in the sky is an illusion caused by the Earth's spin. The Sun appears to rise in the east and move westward throughout the day because the Earth beneath us is spinning eastward, or counterclockwise, as viewed from the north. Therefore, all non-artificial celestial objects have this apparent motion, including the Moon and stars.
6. The Sun is a special object because Earth is in orbit around it. By comparison, the stars are “fixed,” and we measure Earth's “true” rotation—the sidereal day—compared to the stars. Over the course of the sidereal day, Earth has moved along a small portion of its orbit. This causes the Sun to appear to move slightly among the stars from our perspective, and so Earth must spin a few minutes more to “catch up” and bring the Sun back to its position from the previous day. Therefore, the solar day is slightly longer than the sidereal day.
7. At any given time during the year, we can only see the part of the Galaxy that the “night side” of Earth is facing as it orbits the Sun. In July, this part of the Galaxy includes, for example, the stars of Scorpio. Six months later, Earth has moved over to the other side of the Sun, and the night side of Earth is facing an entirely different section of the Galaxy. We cannot see the stars of Scorpio in January because the Sun is between them and us.
8. There are seasons on Earth because the rotation axis of Earth is tilted with respect to the axis of the Sun. This tilt means that a given location on Earth receives different angles and intensities of sunlight over the course of Earth's orbit. When it is summer at your location, the Sun is almost directly overhead at noon. Therefore, the sunlight strikes the ground at almost a 90-degree angle and is very concentrated. In winter, however, the Sun never gets very high, even at noon, and the

sunlight comes in at an extreme angle. This indirect sunlight is very diffuse and not efficient at heating.

9. Discovered by the Greek astronomer Hipparchus, precession is a slow shift in the orientation of the Earth's axis of spin. Although Earth's axis maintains an axis tilt of 23.5 degrees compared to the axis of the Sun, the axis moves in a circle over the course of 26,000 years. This causes the location of the celestial poles to shift, along with the entire sky. It is caused by the gravitational influence of the Moon and Sun on the spinning Earth.
10. Half of the Moon is lit by the Sun at all times. However, due to the Moon's motion around Earth, it is not always the same half. The phase of the Moon depends on which portion of the side of the Moon that faces Earth is lit by the Sun. If 100% of that side is illuminated, we see a full Moon. If none of the side facing Earth is illuminated, we have a new Moon.
11. A lunar eclipse occurs when the Sun, Earth, and Moon align so that the Moon enters the shadow of the Earth. A solar eclipse occurs when the three objects align so that the shadow of the Moon falls on Earth's surface. From the perspective of someone in the shadow, the Moon passes in front of the Sun. Eclipses can only occur when the Sun, Moon, and Earth line up in all three dimensions. This occurs rarely because the orbit of the Moon around Earth is not aligned with the orbit of Earth around the Sun. The two orbits form an angle of 5.2 degrees, so most of the time the shadow of the Moon misses the surface of Earth, and the Moon does not fully enter Earth's shadow. Only on those rare occasions when the three bodies come into alignment and the Moon crosses the plane of Earth's orbit (the ecliptic) can we have an eclipse.
12. So long as the planet's moon (or moons) can enter the shadow of the planet, observers on other planets can see their versions of lunar eclipses. Solar eclipses are a different matter: the moon must be close enough or big enough (or both) to have the same apparent size as the Sun or greater. Only then can it completely cover the Sun from the observer's perspective. This is very possible; for example, we have seen the shadows of the Galilean moons passing over the clouds of Jupiter.
13. Parallax is the apparent shift in a foreground object's position compared to the background. It is an illusion caused by a change in the observer's point of view. For example, when we look at our finger with one eye open and then switch eyes, the finger will appear to move against the background. Surveyors use parallax to find the distances to objects.
14. Since parallax is an illusion caused by a change in perspective, a very large change in perspective (called the baseline) is required to see a parallax shift in a distant object. If the baseline is too small compared to the object's distance, the difference in perspective will not be enough to cause a visible shift.
15. To determine the true diameter of an object from a distance, we need to know how large the object appears to be (the angular diameter) and how far away the object is (distance).